Human–Wildlife Interactions 7(2):195–213, Fall 2013

Putting local knowledge and context to work for Gunnison sage-grouse conservation

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Abstract: Successful conservation requires adequate understanding of focal species and ecology, practices that may assist species survival, and a community of people willing and able to conserve the species. For many species at risk, we operate with imperfect knowledge in complex conservation contexts. In this case study involving the Gunnison sage-grouse (*Centrocercus minimus*), we interviewed 26 community-defined local experts, including both those with and without related academic degrees, to assess the utility of local knowledge for understanding and informing conservation opportunities.This project suggests several benefits of integrating local knowledge that apply specifically to rare and endemic populations, including the ability to gain (1) access to a deeper temporal perspective, (2) observations made during different seasons and life-history stages, and (3) insights regarding the applicability of management strategies formed and science conducted on similar species. The contributions of local experts also can help identify conflicting narratives of species decline and, therefore, important future research directions. The patterns of expert referrals in this project provide evidence that long-term collaboration in conservation has created a pool of local Gunnison sage-grouse experts with technical training and long-term experience. Systematic assessment of the pool of local experts may improve long-term conservation by providing increased insight into the conservation context.

Key words: collaboration, community-based conservation, Endangered Species Act, expert knowledge, Gunnison sage-grouse, human–wildlife conflicts, local knowledge, participatory research, traditional ecological knowledge

Effective conservation requires not only understanding of the species of interest and its political, social, and ecological context, but also a community of people willing and able to act upon that knowledge. While knowledge often is limited for rare and spatially restricted species, there are also barriers to applying that knowledge that have to do with perceived credibility, legitimacy, and salience (Cash et al. 2002). Many rural residents distrust federal agencies and their actions, although they often also express support for species conservation (Conley et al. 2007). Complex problems, including species conservation, are impossible to solve purely with science alone and often require trust-building and stakeholder engagement (Ludwig 2001). Processes of knowledge production that consider local observations and experience often are seen as more fair and credible than those that fail to consider them (Wynne 1992). In this paper, we explore the knowledge that long-term local experts, both formally trained and not, have gained about the Gunnison sage-grouse (*Centrocercus minimus;* Figure 1). We define local knowledge as the knowledge people gain from long-term experience and observation, supplemented by a variety of other sources, such as monitoring, communication with others, and published resources.

Local knowledge has been identified as an important resource to manage natural resources sustainably and to balance resource use with conservation (Eshuis and Stuiver 2005, Berkes 2008). Local experts can help inform application of knowledge and management practices by describing how the local context alters generalized patterns observed elsewhere (Beall and Zeoli 2008, Brinkman et al. 2009, Low et al. 2009). It may also reveal novel observations that can provide hypotheses for future research (Knapp and Fernandez-Gimenez 2009).

Local knowledge also can reveal how different stakeholders perceive and, therefore, respond to the same phenomenon, such as changes in species abundance. In complex situations, with multiple interacting variables, people create narratives to make sense of the phenomena they experience (Foucault 1972). These narratives link information together in a cohesive story that illustrates perceived cause and effect, even if the proof of causality is limited and informed by different assumptions, values, and worldviews (Cronon 1991). In a conservation context, these narratives may influence what conservation actions are taken and the scale at which they are implemented (Campbell 2007). While justified by ecological arguments, these decisions are not apolitical, but are driven by the values of decision makers (Campbell 2007). If unreconciled, different narratives may lead to divergent conclusions about needed conservation actions and make it difficult to apply conservation practices on the ground; highlighting these narratives may help to explore underlying assumptions and stimulate community learning.

Local knowledge gained through experience and management often is marginalized as anecdotal because it fails to meet normative standards of science, such as hypothesis testing, replication, and falsification (Berkes 2008). Individuals with observational expertise often are marginalized in favor of the local knowledge of formal experts, even knowledge claims of formal experts have little proof (Healy 2009, Arnold et al. 2012). However, every type of knowledge has methods to verify its accuracy. For scientific knowledge, verification can include statistical procedures that measure uncertainty, peer review, and the ability to replicate findings. For local knowledge, accuracy often is assessed through comparison of observations, experience, and knowledge in a social process among local experts. In this study, we do not attempt to evaluate the relative accuracy of different knowledge claims, but rather, we document these claims and the relative support for each among local experts to suggest hypotheses for further research.

Sage-grouse are an indicator species for a wide variety of grass and shrubland systems across the western United States, and many sage-grouse are in decline (Schroeder et al. 2004; U. S. Fish and Wildlife Service [USFWS] 2013*a*). Almost 20 years ago, a diverse group of Gunnison Basin residents, including long-term residents, biologists, and agency employees voluntarily came together to address the decline in Gunnison sage-grouse populations. Their efforts have resulted in local and regional conservation plans (Gunnison Basin Local Working Group 1997, Gunnison Sage-grouse Rangewide Steering Committee 2005), >$30 million invested in direct conservation actions (Colorado Parks and Wildlife 2013), and county-level land use regulations. In addition, many local ranchers have changed grazing management practices, fenced riparian areas, and placed conservation easements totaling >40,000 acres in the Gunnison Basin (M. Pelletier, geographic information system [GIS] Specialist for Gunnison County, personal communication). At approximately 4,000 birds, Gunnison sage-grouse numbers within the Gunnison Basin are stable-to-increasing. However, several of the satellite populations continue to decline, and several are thought to be at risk of extinction (U.S. Fish and Wildlife Service 2013*b*). In January 2013, the USFWS proposed that the Gunnison sage-grouse be listed as endangered under the Endangered Species Act (ESA). The USFWS-proposed rule states that current conservation efforts and regulations are not adequate to slow the decline of the species, and that the listing will assist the species by raising public awareness, developing a recovery plan, providing funding for conservation, and by making certain actions illegal (U.S. Fish and Wildlife Service 2013*b*).

Figure 1. Gunnison sage-grouse. Local experts can help inform management practices.

Knowledge of the Gunnison sage-grouse is limited. Current Gunnison sage-grouse population estimates are based on lek (breeding ground) counts, which have been criticized for untested assumptions and inaccuracy (Gunnison Sage-grouse Rangewide Steering Committee 2005), instigating research into new counting methods (Olyer-McCance and St. John 2010, Walsh et al. 2010). Lek counts of Gunnison sage-grouse populations began in 1953 (J. Cochran, Gunnison County Wildlife Conservation Coordinator, personal communication); but early protocols lacked rigor and were inconsistent (Braun 1998). Lek counts were standardized in 1982 to allow year-to-year comparisons (Gunnison Sage-grouse Rangewide Steering Committee 2005). Early baseline population estimates are not comparable with later estimates, and some of the best information can be found in historic journals, surveys, oral histories, and the knowledge of long-term residents. Since recognition of Gunnison sage-grouse as a separate species in 2000 (Young et al. 2000), agencies have monitored populations and produced multiple internal reports about their findings. Such reports provide valuable information that help to inform management decision making.

As is the case for many rare and spatially restricted species, <20 peer-reviewed articles have been published about Gunnison sage-grouse. Research on the species has focused on general natural history (Young et al. 1994), habitat needs during different times of the year (Hupp and Braun 1989, Young et al. 2000, Oyler-McCance et al. 2001, Schroeder et al. 2004, Lupis et al. 2006, Aldridge et al. 2012), genetic diversity of the population (Oyler-McCance et al. 2005, Stiver et al. 2008, Oyler-McCance and St. John 2010, Castoe et al. 2012), the effectiveness of conservation strategies, such as perch deterrents (Prather and Messmer 2010), and removal of non-native species (Baker et al. 2009). The majority of science that is invoked to inform decision making comes from wider-ranging grouse species, especially greater sage-grouse (USFWS 2010). While the biology of the 2 species is similar, extrapolation of scientific findings from 1 species to another may not always be justified (Davis 2012).

Until 2000, Gunnison sage-grouse were not distinguished from greater sage-grouse (Young et al. 2000). The primary differences between the 2 species are size, plumage, courtship display, and genetics (Young et al. 2000). Greater sage-grouse range across much of the western United States and part of Canada and have been deemed warranted for listing under the ESA, but they have been precluded by the need to take action on other species (USFWS 2013*c*). A comparative Web of Science search finds 9 times more results for greater sage-grouse (161) than for Gunnison sage-grouse (18). Research on greater sage-grouse ranges from habitat selection throughout the year to survival of different age classes and from genetics to methods of measuring population size. Research on threats to greater sage-grouse have focused on oil and gas development, which is not considered a threat for the Gunnison sage-grouse population in the Gunnison Basin.

Conservation decision-making always occurs in contexts of incomplete information. In such contexts, the knowledge of local experts may provide information about the species that is otherwise unavailable. Community efforts, such as the original local working group and the current Gunnison Basin Sage-grouse Strategic Committee, have been admirable in their attempts to bring multiple perspectives together, but their goal was to develop and implement conservation strategies, rather than to document local expertise. The USFWS has consulted with grouse biologists about the proposed rule, reviewed local and regional management plans, and accepted comments during the listing process (USFWS 2013*b*). However, there has been no systematic assessment of what local experts know about the species and how that could contribute to conservation efforts.

It is a critical time to pause and reflect about the knowledge that formal and observational experts have gained from a long history of observations and experience with the Gunnison sage-grouse. This project assesses how the knowledge of local experts can contribute to our understanding and conservation of rare species.

Study area

This study took place in the Upper Gunnison River Basin, a high mountain valley dominated by sagebrush steppe lowlands, predominately mountain big sagebrush (Artemisia tridentata) and surrounded by higher-elevation forests of Ponderosa pine (Pinus ponderosa), Douglas fir (Pseudotsuga menziesii), spruce (Picea spp.), and aspen (Populus tremuloides). The elevation ranges from valley bottoms at 2,300 m to high alpine tundra at 2,900 m. The average temperature of Gunnison Basin is 3° C, with an average precipitation of 27 cm. Public lands make up about 80% of the basin, almost all of it used for grazing. Private lands, generally found in the productive river bottoms, account for 30% of Gunnison sage-grouse critical habitat (USFWS 2013b). With approximately 4,000 birds, the Basin contains the largest and most stable of the remaining populations of Gunnison sage-grouse (U.S. Fish and Wildlife Service 2013*b*). The human population of the Gunnison Basin is approximately 23,000 people, primarily in the towns of Gunnison and Crested Butte. The main drivers of the local economy have transitioned from agriculture and ranching to retirees and tourism (Colorado Department of Local Affairs 2010).

Methods

In this study, members of the Gunnison Basin Sage-grouse Steering Committee (GBSC) defined our pool of participants by providing recommendations of local Gunnison sage-grouse experts. The GBSC is comprised of 25 people, including 12 formal experts and 13 observational experts (as defined below) whose mission is to implement programs and steps that will aid in the preservation of Gunnison sage-grouse (Gunnison County 2013). We began by asking GBSC members to identify who they thought knew the most about Gunnison sage-grouse. We sent an e-mail to each committee member and followed with up to 2 reminder calls. We were able to gain references from 80% of the committee members. As the study progressed, we also asked participants to refer others. We did not set a limit to the number of recommendations, and numbers ranged from 1 to 34, with an average of 10 recommendations per referee; 88 individuals were identified as local experts (formal and observational). We prioritized potential participants based on the number of referrals. There were 39 people with ≥3 referrals, and we were able to speak with twenty-six of them (Table 1). This included all the individuals with 4 or more referrals, and 70% of those with at least three. Although this method may fail to include all local experts, perhaps because they are no longer active in Gunnison sage-grouse issues or were less well-known, we believe that this process was able to identify the individuals who the people most engaged in Gunnison sage-grouse issues (i.e., the GBSC) define as local experts.

Individuals included as experts were those having long-term local observations, technical training, or both. Their knowledge came from a variety of sources, including experience (e.g., active management of ranches, employees for land management agencies), scientific research, or communication with one another. Their knowledge was not purely local or scientific, but a hybrid of both (Turnbull 1997, Fazey et al. 2006). All of the participants were considered local experts, as defined by their own community. We differentiated 2 categories within local experts: (1) observational experts who gained most of their knowledge through direct observation but lacked formal training and (2) formal experts who had an academic degree related to biology or ecology and conducted systematic monitoring or research on Gunnison sage-grouse. Observational experts included ranchers, long-time residents, non-biologists, agency employees, and politicians, while formal experts included agency or academic biologists. These categories were not exclusive, and there were observational experts who were well-versed in the scientific literature, as well as formal experts who had long-term observations. The objective of these categories was to provide a way to compare individuals with and without formal training.

We developed an open-ended interview script based on our research question that covered knowledge of habitat, behavior, ecology, conservation strategies, and threats to Gunnison sage-grouse. We received approval for conducting these interviews through the Institutional Review Board at the University of Alaska Fairbanks (Approval 369551-1). Semi-structured interviews occurred in July and August 2012, and each interview ranged from 40 minutes to 2.5 hours. Interviews were transcribed in full and coded in NVIVO (QSR International, Burlington, Mass.), a qualitative coding software program. We developed a preliminary coding plan based on research questions and added emergent codes as themes of interest were identified; NVIVO facilitates the systematic analysis of data, or quotes, related to each theme of interest. A single researcher coded all interviews twice to confirm that all themes of interest were captured.

Our analysis includes both qualitative content analysis and quantitative counts of participants who referenced specific themes. We used triangulation across interviews and with published research to find corroborating data (Denzin and Lincoln 2005). We also used negative case analysis to look for evidence that contradicted our preliminary findings (Denzin and Lincoln 2005). We did not use statistical analyses because of the non-random sample, small sample size, and open-ended nature of many of the interview questions. Our primary research question was whether and how local expert knowledge could inform conservation decision-making. Interviews and content analysis allowed us to collect the rich qualitative data needed to address this question.

We were also interested in the network of community referrals and what they said about how knowledge was held and valued within the community. To explore this question, we tallied how many times that each type of expert (formal and observational) referred other experts. We were interested in who referred whom and the total number of referrals given and received (Table 1; Figure 2).

Results

Who are the experts?

The GBSC and project participants made 299 individual referrals. Individuals without formal training provided more referrals (204) than did those with formal training (95). Individuals with formal training referred formal and observational experts almost equally (Figure 3), while individuals without formal training were more likely to refer other observational experts (Figure 2). However, both groups recommended individuals who did not share their background. The GBSC and project participants identified 88 knowledgeable people. Of the 83 people in the network who we were able to identify, there were slightly more observational (45) than formal (38) experts. We interviewed 26 people, including 12 formal and 14 observational experts who received the most referrals (Table 1, column 3). On average, interviewees had 16 years of experience with Gunnison sage-grouse, and 29 years of experience in the Gunnison Basin. Respondents were primarily male (80%), with several women (12%) and 2 couples (8%).

Types of observations

Different local experts shared different types of information, with some contributing information about Gunnison sage-grouse biology and others more knowledgeable about Gunnison sage-grouse management or Gunnison sage-grouse habitat (Table 1, column 6). Most (21; 81%) local experts made their observations of sage-grouse primarily in the spring, summer or fall (Table 1, column 7). Only 5 participants (19%) described ongoing observations during the winter. The majority (7; 58%) of the formal experts described observations primarily in the spring during lekking. Formal experts said they made their observations during lek counts or as part of official research activities, while observational experts made observations opportunistically when they were engaged in other activities (e.g., moving cattle, irrigating, etc.).

Historical memory about Gunnison sage-grouse

Long-time residents were unanimous in recollecting much larger populations of Gunnison sage-grouse in the past. As 1 resident expressed, "They had a regular hunting season for them and we would all go sage-grouse hunting and easily fill your limit, there were so many. In fact, when you were riding a spooky horse you had to be awake because they would jump when the sage-grouse flushed, and we flushed a lot of them." Long-term residents also described a decrease in numbers of cattle and an increase in predators over time.

Habitat use and quality

Local knowledge of habitat mirrored the scientific literature. Local experts consistently described the importance of intact sagebrush steppe with a diverse understory of grasses and forbs and proximity to wet or riparian areas (Young et al. 2000). When asked where they were

Table 1. Characteristics and opinions of study participants.

Primary category	Subcategory	Number of referrals	Years in area	Years aware of Gunnison sage-grouse	Area of expertise[a]	Season of observation[b]	Endangered?[c]	Should survive?[d]	How would listing impact Gunnison sage-grouse?[e]
Formal expert	Biologist	3	0	2	B, E, M	**SP,** S	D	Y	+
Formal expert	Biologist	3	13	5	B, C, M	SP, S	N	Y	+
Formal expert	Biologist	4	16	6	B, E, HA, M	**SP, S, F,** W	D	Y	Neutral
Formal expert	Biologist	4	17	17	E, HA	SP, S, F, W	N	Y	Neutral
Formal expert	Biologist	6	12	11	B, C, E, HA	**SP,** F, W	N	Y	+
Formal expert	Biologist	6	13	7	B, E, HA, M	**SP,** S, F	N	Y	-
Formal expert	Biologist	6	24	24	B, C, E, HA, GH	SP, S, F	Y	Y	+
Formal expert	Biologist	6	16	16	B, C, E, HA	**SP**	Y	Y	Neutral
Formal expert	Biologist	7	7	7	C, E, HA, M	SP, F	N	Y	+
Formal expert	Biologist	7	8	8	B, C	SP, F	N	Y	Neutral
Formal expert	Biologist	9	9	16	B, C, M	SP, S, F	N	Y	Neutral
Formal expert	Biologist	12	15	15	C, E, HA, M	SP, S, F	N	Y	-
Observational expert	Non-biologist agency	3	30	17	E, H, M	SP, S, F	N	Y	+
Observational expert	Non-biologist agency	3	30	22	E, GH, M,S	SP, S, F	Y	Y	+

Continued on next page.

Table 1 continued.

Primary category	Subcategory	Number of referrals	Years in area	Years aware of Gunnison sage-grouse	Area of expertise[a]	Season of observation[b]	Endangered?[c]	Should survive?[d]	How would listing impact Gunnison sage-grouse?[e]
Observational expert	Non-biologist agency	5	31	27	M, S	SP, S, F	N	Y	Neutral
Observational expert	Non-biologist agency	6	15	15	B, E, M	SP	N	Y	+
Observational expert	Rancher	3	94	30	GH, H, S	SP, S, F	N	M	Neutral
Observational expert	Rancher	4	79	30	E, GH, H, M, S	**SP**, S, W	N	Y	-
Observational expert	Rancher	7	55	30	E, GH, H, M, S	**SP, S**, F, W	Y	Y	Neutral
Observational expert	Rancher	9	70	20	GH, H, M, S	SP, **S**	N	Y	Neutral
Observational expert	Rancher	15	43	17	E, GH, H, M, S	**S**, F	N	Y	-
Observational expert	Resident	3	56	30	B, E, GH, M	SP, **S**, F	D	Y	+
Observational expert	Resident	4	30	10	S	SP	N	M	Neutral
Observational expert	Resident	5	25	5	M, S	**SU**, F	N	Y	+
Observational expert	Resident	7	20	12	S	S	Y	M	Neutral
Observational expert	Resident	10	40	17	M, S	**SP**, S	Y	Y	+

[a] Refers to the primary area(s) of expertise for each participant (B = biology; C = comparison with GRSG; E = ecology; H = history; HA = habitat; GH = grouse history; M = management; S = representative of stakeholder group).
[b] Refers to the primary season in which participants observe GUSG (**Boldface** = primary season of observation [if applicable]; SP = spring; S = summer; F = fall; W = winter).
[c] Refers to wheither the participant feels that GUSG is endangered in the Gunnison Basin population (Y = yes; N = no; D = do not know).
[d] Refers to whether the participant feels it is important that GUSG survive in the future (Y = yes; N = no; M = maybe (depends on impacts to economy and livelihood)]
[e] Refers to whether the participant thinks the ESA listing of GUSG will have a positive (+), negative (-) or neutral impact on GUSG.

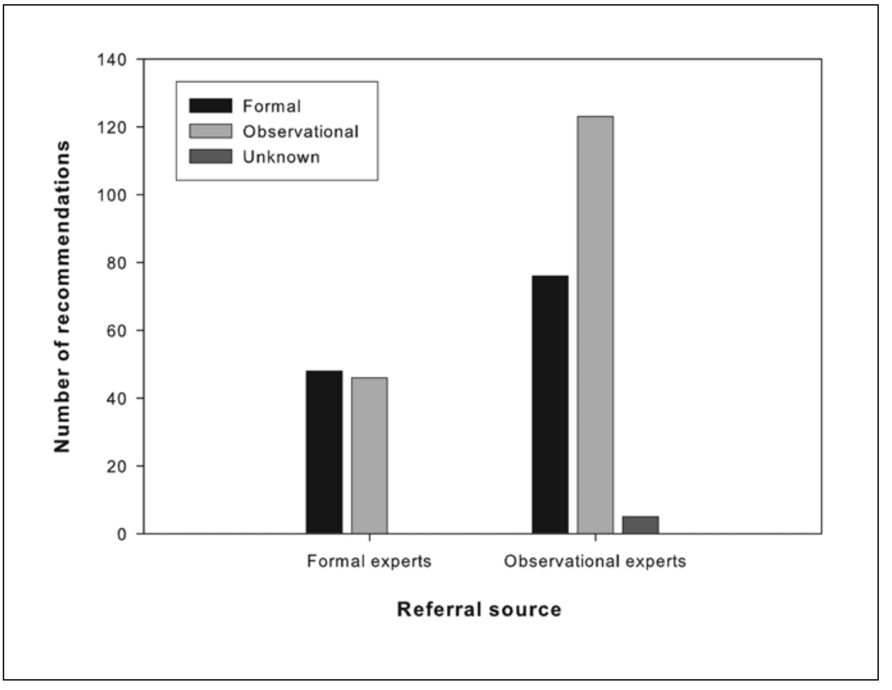

Figure 2. Number and type of referrals from observational and formal experts.

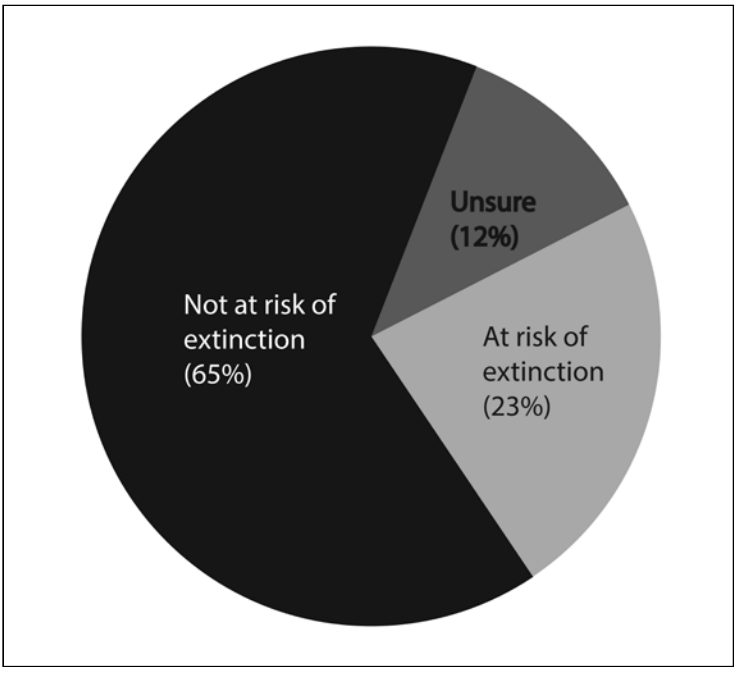

Figure 3. Participant opinions about whether Gunnison sage-grouse are at risk of extinction in the Gunnison Basin.

sure to see Gunnison sage-grouse, participants described mesic areas and drainages with more diverse understory. As one stated, "I think there were a lot in sagebrush and grass, but if you go up the little streams you would always see some."

Novel insights related to use and importance to sage-grouse of hay meadows, small

Table 2. Novel observations of Gunnison sage-grouse habitat and behavior and the evidence corroborating or conflicting from the published literature.[a]

Observation	Total	Formal	Observational	Corroborating	Conflicting
Habitat					
Use of hay meadows	8	4	4	Young et al. 2000[b]	
Importance of serviceberry	5	5		Young et al. 2000[c]	
Use of snow caves	6	4	2		
Use of edge habitats	6	5	1		
Use of higher elevations	8	5	3		
Overlapping habitats	3	3		Aldridge et al. 2012[d]	
Behavior					
Prone to flushing	7	7			
Less territorial on leks	4	4			
Move with cattle	4		4	Lupis et al. 2006[e]	Lupis et al. 2006[e]
Observed in water	4	2	2		

[a] Evidence was drawn only from published peer-reviewed articles related to Gunnison sage-grouse
[b] This study mentions the use of pastures.
[c] This study mentions the use of serviceberry.
[d] This study describes crucial nesting habitat and suggests overlap with other life-stage habitat.
[e] This study showed that males and broodless hens avoided sites during and after grazing, but the hen with a brood used them.

Table 3. Number of participants who mentioned threats to Gunnison sage-grouse and the perceived magnitude of each threat.

	Total (n = 26)	Observational expert (n = 14)				Formal expert (n = 12)			
Threat	Overall (%)	Overall (%)	Low threat (%)	Medium threat (%)	High threat (%)	Overall (%)	Low threat (%)	Medium threat (%)	High threat (%)
Predation	84.6	78.6	14.3	35.7	28.6	91.7	83.3	8.3	
Recreation	80.8	71.4	7.1	50.0	14.3	91.7	16.7	66.7	8.3
Habitat modification	69.2	57.1		28.6	28.6	83.3		8.3	75.0
Grazing (cattle—historic)	65.4	42.9	7.1	28.6	7.1	91.7		41.7	50.0
Drought	57.7	42.9		42.9		75.0		8.3	66.7
Grazing (cattle—current)	57.7	42.9	21.4	14.3	7.1	75.0	33.3	41.7	
Grazing (elk and deer)	46.2	42.9	14.3		28.6	50.0	8.3	33.3	8.3
Invasive species	42.3	35.7	35.7			50.0	16.7	33.3	
Research	19.2	7.1		7.1		33.3	16.7	8.3	8.3
Sagebrush treatments	19.2	14.3	14.3			25.0	8.3	16.7	

serviceberry islands in the sagebrush steppe, use of snow caves, and several odd but recurring observations in edge habitat and at high elevations (Table 2). Participants (8; 31%) commonly described use of hay meadows for lekking and brood-rearing. Such sites may have been historic leks prior to conversion, but there was evidence that Gunnison sage-grouse were still able to use these landscapes productively. One of the largest currently active leks in the basin is in a hay meadow. Several participants stated the importance of introduced clover as part of the grouse diet and the ability of irrigated hay meadows to substitute for seeps, springs, and riparian areas. Participants described how small islands of serviceberry were important to conserve because they are mesic sites that often contain forbs (5; 19%) needed by sage-grouse. Several participants also talked about Gunnison sage-grouse use of snow caves for thermal insulation and described how cold, low-snow years could be more detrimental than high-snow years because of the importance of snow caves (6; 23%). Participants also suggested use areas above 2,804 m (8; 31%) and use of the sagebrush–forest interface (23%: 6). Individuals observed Gunnison sage-grouse using these areas and tracked their movements radio collars. While 1 peer-reviewed paper mentioned the use of pastures and serviceberry, few of these claims were documented in the published and peer-reviewed literature (Table 2).

Several of the formal experts (3; 25%) talked about a different landscape–habitat pattern

Table 4. Number of interview participants who described each of the following conservation strategies for the Gunnison sage-grouse as beneficial, not beneficial or were unsure about the benefit.

	Beneficial			Unsure about benefit			Not a benefit		
Strategy	Total % (n = 26)	Observational expert % (n = 14)	Formal expert % (n = 12)	Total % (n = 26)	Observational expert % (n = 14)	Formal expert % (n = 12)	Total % (n = 26)	Observational expert % (n = 14)	Formal expert % (n = 12)
Better science	31	14	50						
Candidate conservation greements	15	14	17						
Conservation easements	38	29	50						
Control weeds	12	7	17						
Fire	35	29	42	23	14	33	8	7	8
Grazing practices (new)	46	36	58	4	7				
Interseeding	27	36	17						
Marking fencelines	4		8				8	14	
Mowing leks	15	7	25						
Perching deterrents							4		8
Predator control	31	50	8	35	29	42	19	7	33
Development regulations	12	7	17				8	14	0
Restoration	50	29	75						
Road closures	38	36	42	4		8			
Sagebrush treatments	15	7	25	27	29	25	23	7	42
Transplanting	4		8				8	7	–8

in which the types of Gunnison sage-grouse habitat in this area were overlapping and continuous, making it difficult to identify important habitats. As 1 participating biologist stated, "They [Gunnison sage-grouse] are using a much wider landscape, and, you know, just the fact that you see so much overlap with those seasonal habitats I think is pretty important because we are trying to think about these boxes of brood-rearing, winter and nesting, but, really, it all overlaps in all the areas." Such formal experts (3; 25%) stated that this makes it questionable to adapt habitat guidelines created for other grouse species to Gunnison sage-grouse. One recent publication describes the large area needed for crucial nesting habitat and suggests important overlap between other life-stage habitats (Aldridge et al., 2012).

Behavior of Gunnison sage-grouse

Gunnison sage-grouse behavior is fairly similar to that of other sage-grouse. However, participants in the study also mentioned several behavioral characteristics that are rarely noted in the literature: Gunnison sage-grouse are more prone to flushing in response to disturbance than greater sage-grouse, they are less territorial on the leks than greater sage-grouse, have been seeing moving with cattle, and have been observed in shallow water (Table 2). Seven (27%) participants who had observed both greater sage-grouse and Gunnison sage-

Table 5. Most commonly suggested research needs related to Gunnison sage-grouse.

Research need	Total	Observational expert	Formal expert	Example quote
Interaction between grazing and Gunnison sage-grouse	12	5	7	"I don't think we understand that at all: the relationship between cattle and Gunnison sage-grouse. I think there are things that cattle do and provide that the Gunnison sage-grouse like, but we could never find out and if it is negative. That is ok, but I want to know and we don't know."
Increased science to inform decision-making	11	6	5	"I have always had the sense that there is still a lot about protecting things rather than answering the hard questions and following the answers wherever they go."
Monitoring sagebrush treatments to assess conservation outcomes	7	2	5	"I would like to see more studies to try to figure out some of those things that we don't know as well as we should know to manage the species well. Our management has to be based on as good of science as we can get and it is never easy to get good research to support your management decisions in a reasonable timeframe."
How local activities impact Gunnison sage-grouse populations (closures, dogs, recreation)	7	3	4	"Does a mountain bike have the same disturbance as a truck checking coal sites or the normal road disturbance to oil and gas pad? We are having a problem because a lot of the science is focusing on that because it is the biggest disturbance, but what is the disturbance of someone walking or a car on a normal road once a week?"
Habitat preference at micro- and meso-scale	7	3	4	"What are the micro-site characteristics that they need? We say they need to get from the nest to a mesic area but what that area is and what it looks like…we need a better understanding of that."
Impact of predation on Gunnison sage-grouse	6	2	4	"We have very little [science] about predator control, but that is the one thing we really haven't taken more of a shot at. I would look to put some dollars there."

grouse stated that Gunnison sage-grouse are more prone to disturbance and more difficult to capture. Several people noted that they are more likely to flush due to predators or human interference and then fail to return to the lek, while other species (e.g., greater sage-grouse) will merely crouch down and then quickly return to dancing. This observation has not been documented in the peer-reviewed literature.

Several participants (4; 15%) also mentioned Gunnison sage-grouse are less territorial on leks than that of greater sage-grouse, with males more willing to move to females and less defensive of individual dancing areas. This observation has also not been documented in the peer-reviewed Gunnison sage-grouse literature. Four ranchers, who are 1 type of observational expert, described seeing sage-grouse following cattle, both as protection from predators and to feed off grubs left in cow manure. One rancher noted that the birds felt secure with cattle because they knew there would be no threat from coyotes. Lupis et al. (2006) showed that males and broodless females avoided grazing cattle, although the authors noted that 1 female with a brood continued to use the pasture. Four participants also noted observations of Gunnison sage-grouse in shallow open water, which we could find no mention of in the literature.

Threats to the survival of Gunnison sage-grouse

We asked each participant to list threats to Gunnison sage-grouse and describe the level of each threat they mentioned (Table 3). Participants described the threats that they felt were most important, and not every person mentioned every threat. Most (69%) participants agreed that modification of habitat was a medium or high threat to Gunnison sage-grouse. Other commonly mentioned threats included predation, recreation, and grazing. However, many of these threats were given different weights by different groups. For instance, experts differed in their evaluation of the threat level of predation (observational experts = medium to high threat; formal experts = low threat), historic cattle grazing (observational experts = medium threat; formal experts = high threat), current cattle grazing (observational experts = low threat; formal experts = medium threat), and drought (observational experts = medium threat; formal experts = high threat).

Strategies to conserve Gunnison sage-grouse

We asked each participant to list conservation strategies for Gunnison sage-grouse and whether they were beneficial, not beneficial, or if they were unsure about the benefit (Table 4). Participants described conservation strategies that they were familiar with, but not every participant mentioned every strategy. The most commonly referenced beneficial strategies included restoration (13; 50%), improvements in grazing practices (12; 46%), conservation easements (10; 38%), and road closures (10; 38%). Other strategies, including predator control, mechanical sagebrush treatments, and fire, were contested. Half of the observational experts felt predator control was beneficial, while most formal experts were unsure (5; 42%) or felt that it was not a benefit (4; 33%). About a quarter (7; 27%) of participants were unsure about the benefits of mechanical sagebrush treatments, and formal experts often felt it was not an effective strategy (5; 42%). Fire had some support from each participant group (9; 35%), but a proportion of each group was unsure about its effects (6; 23%).

Research needs

Participants were asked what they felt were the most pressing research questions regarding Gunnison sage-grouse (Table 5). Common concerns included the relationship between grazing and Gunnison sage-grouse (12; 46%) and better science to inform decision-making (11; 42%). Observational and formal experts overlapped on many of the research questions they felt were most relevant.

Opinions and beliefs about Gunnison sage-grouse listing as endangered

Participants were almost unanimous (23; 88%) that it was important that Gunnison sage-grouse survive in the future (Table 1, column 9). Most of the participants described personal observations and concern over decline of Gunnison sage-grouse within their lifetime, but few felt that Gunnison sage-grouse in the Gunnison Basin were at risk of extinction (Figure 3). About 50% of those who had knowledge of the Gunnison sage-grouse satellite populations agreed that the birds were at risk of becoming extinct in the next 50 to 100 years. Several (3; 11%) participants stated that the threat of listing has been useful for getting people to work together. Some observational experts (5; 36%) felt that the listing of the Gunnison sage-grouse was being used as a lever to prevent development and curtail grazing on public lands, and not primarily to protect the species.

We were also interested in what people expected would be the likely outcomes of listing the Gunnison sage-grouse as an endangered species under the ESA. About a quarter of the participants were unsure how the listing would directly impact them (7; 27%), while many formal experts were concerned about additional workload (6; 50%), and a sub-group of observational experts (ranchers) were concerned about their continued access to public lands (4; 80%). Almost half of the participants (11; 42%) were concerned that the listing would frustrate stakeholders, potentially decreasing engagement in and support of future conservation efforts. However, many of this same group said that lowered cooperation wasn't inevitable (7; 64%) and could be countered with transparent communication and building on current endeavors. Other respondents (8; 31%) felt that the listing would not have a large impact on the community, because the county government and agencies were already managing as if the bird were listed. This group also cited 2 programs, the Candidate Conservation Agreement (for public land) and Candidate Conservation Agreement with Assurances (for private land), as measures that would minimize the impact by establishing guidelines for management prior to a listing decision. Finally, we asked participants to reflect on what the outcomes of the listing would be for the Gunnison sage-grouse. Participants were split between feeling the listing would be positive or neutral, with four (15%) thinking listing would be negative for the sage-grouse (Table 1, column 10). The overall pattern held for both subgroups, with two of each feeling the listing was negative and the remainder split between neutral and positive.

Discussion

The conservation landscape for the Gunnison sage-grouse has shifted. After 20 years of local conservation actions to protect the Gunnison sage-grouse, the USFWS has proposed to list this species as endangered under the ESA (USFWS 2013*b*). Given both the long-term local conservation efforts and expertise and the minimal scientific research on this species, we felt thatthis was a crucial time to assess local knowledge and how it might inform management decisions as conservation efforts move forward.

Knowledge networks

Community-based natural resource management has been lauded for its ability to build understanding about resources, make wise decisions, build local capacity, and get projects done on the ground (Wondolleck and Yaffee 2000, Kofinas et al. 2002, Berkes 2004, Peloquin and Berkes 2009). In this project, we found that an additional benefit of engaging communities in conservation is that it can create a network of local experts that includes conventionally recognized formal experts, such as biologists, as well as observational experts, such as ranchers and long-time residents. Co-production of knowledge, the ability to share knowledge, learn from one another, and generate new discoveries, is increasingly recognized as an important element for effective community engagement in resource management (Edelenbos et al. 2011, Hegger et al. 2012). In past studies, researchers often have found it challenging to bridge observational and formal knowledge because of issues of legitimacy (Edelenbos et al. 2011). However, after 20 years of cooperation on the Gunnison sage-grouse, our referral network demonstrates that participants in the GBSC identify and value the insights of people with different types of experience with Gunnison sage-grouse. Rural residents often demonstrate skepticism and distrust of federal regulations, such as the ESA (Stokstad 2005). At this point, prior to the listing decision, it is important that informal networks of local experts, such as the ones identified in this paper, be sustained to mitigate distrust and to access knowledge drawn from the extensive experience of both observational and formal experts. This could be accomplished by building on efforts of the

GBSC to help inform and guide conservation actions post-listing.

Value of local knowledge

There has been increased interest in the value of local knowledge for decision-making in the past 2 decades, to address data gaps, provide novel information, inform adaptive governance, and contribute not just information but wisdom about appropriate use of resources (Berkes 2008, Chapin et al. 2009). This project suggests several benefits of applying local knowledge to rare and endemic populations including providing access to (1) a deeper temporal perspective, (2) observations made during different seasons and life-history stages, and (3) insight into the applicability of management strategies formed on the basis of research on similar species. In complex and contested conservation contexts, speaking with local experts also helps to (1) provide an assessment of local values and motivations, (2) better understand current controversies (Tables 3, 4), and (3) highlight important research questions.

Deeper temporal perspective. Observational experts had long-term experience in the region (Table 1, columns 4, 5) and provided information about sage-grouse abundance and from personal memories and oral histories that were otherwise patchy or unavailable. Experts provided insights about a range of associated factors (e.g., predator populations, domestic grazer populations, native ungulate populations) that may help to inform both our understanding of these ecosystems and the narratives that local experts use to explain declines in Gunnison sage-grouse populations.

Observations made during different seasons and life-history stages. Because formal and observational experts made their observations at different times of the year, the timing and intensity of observations can complement one another (Table 1, column 7). Formal experts made most of their observations during spring or other seasonally specific research projects, while observational experts made observations year-round while conducting other activities. Formal experts were more systematic in their observations and included processes designed to count, measure, and track Gunnison sage-grouse to answer specific questions, while observational experts provided qualitative observations across a larger landscape that is otherwise rarely monitored.

Appropriate local application or hypotheses for further research. Participants offered several novel insights about Gunnison sage-grouse that may have implications for the local application of science developed for other species and management strategies designed in other places. For instance, observations suggest that Gunnison sage-grouse can be flushed from leks more readily than other sage-grouse species and are less likely to return to leks after disturbance, which might inform regulations on new development activities, lek-viewing activities, or recreation. The overlap among habitat types suggests a more integrative form of land conservation that includes both conservation of a range of important types of habitat, as well as corridors to link them. Local observations may also provide new hypotheses for future research. For instance, observations of the importance of hay meadows and serviceberry stands could inspire researchers to study the role of these landscape components in the life history of Gunnison sage-grouse and the potential for current management practices on private lands to contribute to Gunnison sage-grouse conservation.

Assessment of local values and motivations. All of the participants expressed concern over the decline in Gunnison sage-grouse, and the majority of them expressed their opinion that it was important that Gunnison sage-grouse survive in the future. Many of the participants have been working on the conservation of the Gunnison sage-grouse for >20 years. Despite this demonstrated commitment, only about a quarter (6; 23%) felt that Gunnison sage-grouse were at risk of extinction. The primary explanation given by participants was that they believed that endangered species status would not provide any greater conservation potential than local conservation efforts had already done, and they were concerned that listing might derail current community conservation efforts. Similar concerns have been raised over the listing of Attwater's prairie chicken (*Tympanuchus cupido attwateri*), but efforts to maintain good working relationships with stakeholders have overcome these concerns (Morrow et al. 2004). If the proposed listing is approved, it is important that the USFWS foster open and ongoing communication, as well as build upon existing conservation efforts.

Better understanding of current controversies. Our project highlighted the controversies that still exist surrounding conservation practices and threats. We identify these controversies by looking at the level of disagreement surrounding threats (Table 3) and conservation strategies (Table 4). Predators, grazing, and sagebrush manipulations were 3 topics where there was considerable disagreement among local experts. These are also topics where there is very little science or ongoing monitoring to substantiate either side of the arguments.

Important future research questions. Interviews with local knowledge holders helped to identify a range of critical research questions that were common across participant types and linked to the controversies described above (Table 5). Pursuing answers to these questions may assist the community in moving forward with effective management strategies regarding sagebrush manipulation, grazing, and predators. Research that is driven by end users is more likely to be applied to management than research that does not consider end users (Danielsen et al. 2005). In contested contexts such as this one, where values are difficult if not impossible to separate from fact, it is important to bring diverse stakeholders together to design and implement research to inform decision-making (Jasanoff, 2004).

Limitations of local knowledge

Local knowledge, including scientific knowledge, can be inaccurate, partial, or biased. It is important to locate the most knowledgeable local residents (Davis and Wagner 2003), which in our study were identified through documenting referrals and prioritizing individuals with ≥3 referrals. In highly controversial contexts, such as that surrounding the listing of an endangered species, individuals (whether formal or observational experts) may have the incentive to provide information that supports their beliefs (Lewicki et al. 2003). In these situations, it is important that individual observations should be treated as hypotheses until they are substantiated by additional observations, monitoring data, or research. Since local knowledge is collected in specific places at specific times, it is also important to understand the spatial and temporal bounds of local knowledge. For instance, observations in the Gunnison Basin population may not be applicable to other Gunnison sage-grouse populations because of differences in context (e.g., land use, predator populations, weather patterns). Science is typically better at elucidating certain aspects of ecosystem dynamics that are difficult to directly observe, such as the nutritional value of different vegetation and the genetic diversity in sub-populations. However, scientific studies also are collected in specific times and places, although their methods attempt to abstract from those contextual factors.

Questioning conservation narratives

Formal (e.g., from biologists) and observational (e.g., from ranchers, long-term residents, and non-biologist agency employees) viewpoints have their own narratives about why sage-grouse populations have declined and what could be done about it. As others have found, conservation narratives link together ecological theory, research results, values, beliefs and observations to explain conservation dilemmas and propose potential solutions (Campbell 2007). In the Gunnison context, it is clear that there are 2 prevailing narratives about the ecosystem. Most formal experts share a narrative that suggests that habitat modification, drought, and historic grazing have caused decreases in grouse populations, and the solution is in restoration, changed grazing practices, conservation easements, and better science. Most observational experts share a different narrative that proposes that predation, recreation, and habitat modification have resulted in decreased Gunnison sage-grouse populations, and the solutions include predator control, road closures, inter-seeding, and changed grazing management practices. These narratives structure the way we understand what the problem is and how it should be addressed (Cronon 1991). In controversial situations, the narratives of formal experts, even if unsupported by data, often are accepted as less biased than those of observational experts (Healy 2009, Arnold et al. 2012). This assumption often leads to lack of cooperation between formal and observational experts, as well as adoption of potentially maladaptive solutions because critical information may be ignored and because observational experts, who are often also managers, are less inclined to support decisions in which they have not participated (Wynne 1992).

The first step toward a shared understanding is the recognition of different narratives. Many of those active in the Gunnison sage-grouse issue will recognize these different narratives, but may not have taken the step of considering the limits of the evidence behind their own narrative. As Gunnison sage-grouse conservation efforts move forward, it will be important that all available information is brought to bear in management decision-making. This will mean consideration of existing peer-reviewed literature, internal agency reports and monitoring data, as well as the insights of long-time local observers. The resulting integration of knowledge has the greatest potential to inform and identify solutions to current debates about best practices that can lead to beneficial outcomes for Gunnison sage-grouse.

Conclusions

Worldwide, many species of grassland birds face multiple threats. Their long-term survival requires a new level of partnership and respect among observational and formal experts. This study demonstrated that engaging local knowledge can provide benefits for understanding rare and endemic species, as well as informing conservation in contested contexts. Local experts can provide a deeper temporal perspective, information on a broader spatial scale and in different seasons, and insight about how to apply knowledge gained in other locations and with other species. Local experts can also help to understand values and highlight controversies that, if not informed by research, might stall conservation efforts. There are 2 interacting components to any conservation challenge: the social and the ecological. The findings from this project suggest that local experts can inform our understanding of species biology, as well as the social context in which conservation occurs.

Acknowledgments

Many thanks to the local experts who shared their knowledge and experience with Gunnison sage-grouse. Thanks also to N. Fresco and C. Carothers who provided valuable feedback on previous drafts of this manuscript. We appreciate feedback received from 3 anonymous reviewers whose suggestions improved this paper. Funding was provided by Gunnison County, the City of Gunnison, Upper Gunnison Water Conservancy District, the Redd Foundation, and an IGERT fellowship from the National Science Foundation.

Literature cited

Aldridge, C. L., D. J. Saher, T. M. Childers, K. E. Stahlnecker, and Z. H. Bowen. 2012. Crucial nesting habitat for Gunnison sage-grouse: a spatially explicit hierarchical approach. Journal of Wildlife Management 76:391–406.

Arnold, J. S., M. Koro-Ljungberg, and W. Bartels. 2012. Power and conflict in adaptive management: analyzing the discourse of riparian management on public lands. Ecology and Society 17:19.

Baker, W. L., J. Garner, and P. Lyon. 2009. Effect of imazapic on cheatgrass and native plants in Wyoming big sagebrush restoration for Gunnison sage-grouse. Natural Areas Journal 29:204–209.

Beall, A., and L. Zeoli. 2008. Participatory modeling of endangered wildlife systems: simulating the sage-grouse and land use in central Washington. Ecological Economics 68:24–33.

Berkes, F. 2004. Rethinking community-based conservation. Conservation Biology 18:621–630.

Berkes, F. 2008. Sacred ecology. Routledge, New York, New York, USA.

Braun, C. E. 1998. Sage-grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139–156.

Brinkman, T. J., F. S. Chapin, G., Kofinas, and D. K. Person. 2009. Linking hunter knowledge with forest change to understand changing deer harvest opportunities in intensively logged landscapes. Ecology and Society 14:36.

Campbell, L. M. 2007. Local conservation practice and global discourse: A political ecology of sea turtle conservation. Annals of the Association of American Geographers 97:313–334.

Cash, D. W., W. C. Clark, F. Alcock, N. E. Dickson, and J. Jager. 2002. Salience, credibility, legitimacy and boundaries: Linking research, assessment and decision-making. Harvard University Faculty Research Working Papers, John F. Kennedy School of Government, Harvard University, Cambridge, Massachusetts, USA.

Castoe, T. A., A. W. Poole, A. P. J. de Koning, K. L. Jones, D. F., Tomback, S. J. Oyler-McCance, J. A. Fike, S. L. Lance., J. W. Streicher, E. N. Smith, and D. D. Pollock. 2012. Rapid microsatellite identification from illumina paired-end genomic sequencing in two birds and a snake. Plos One 7, <http://www.plosone.org/article/info:doi/10.1371/journal.pone.0030953>. Accessed July 18, 2013.

Chapin, F. S., G. P.,Kofinas, C. Folke, and M. C. Chapin. 2009. Principles of ecosystem stewardship resilience-based natural resource management in a changing world. Springer, New York, New York, USA.

Colorado Department of Local Affairs. 2010. Regional profile: West Central Colorado. <http://dola.colorado.gov/dlg/demog/profiles/region10.pdf>. Accessed July 18, 2013.

Colorado Parks and Wildlife. 2013. Gunnison sage-grouse: species of special concern, <http://wildlife.state.co.us/WildlifeSpecies/Profiles/Birds/Pages/Gunnisonsagegrouse.aspx. Accessed July 18, 2013.

Conley, J. L., M. E. Fernandez-Gimenez, G. B. Ruyle, and M. Brunson. 2007. Forest Service grazing permittee perceptions of the Endangered Species Act in southeastern Arizona. Rangeland Ecology and Management 60:136–145.

Cronon, W. 1991. A place for stories: nature, history and narrative. Journal of American History 78:1347–1376.

Danielsen, F., N. D. Burgess, and A. Balmford. 2005. Monitoring matters: examining the potential of locally-based approaches. Biodiversity and Conservation 14:2507–2542.

Davis, A., and J. R. Wagner. 2003. Who knows? On the importance of identifying “experts” when researching local ecological knowledge. Human Ecology 31:463-486.

Davis, A. 2012. Gunnison sage-grouse demography and conservation. Dissertation, Colorado State University, Fort Collins, Colorado, USA.

Denzin, N. K., and Y. S. Lincoln. 2005. The SAGE handbook of qualitative research. Sage Publications, Thousand Oaks, California, USA.

Edelenbos, J., A. van Buuren, and N. van Schie. 2011. Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. Environmental Science Policy 14:675–684.

Eshuis, J., and M. Stuiver. 2005. Learning in context through conflict and alignment: farmers and scientists in search of sustainable agriculture. Agriculture and Human Values 22:137–148.

Fazey, I., J. Fazey, J. A. Salisbury, D. B. Lindenmayer, and S. Dovers. 2006. The nature and role of experiential knowledge for environmental conservation. Environmental Conservation 33:1–10.

Foucault, M. 1972. The archaeology of knowledge. Random House, New York, New York, USA.

Gunnison Basin Local Working Group. 1997. Gunnison sage-grouse conservation plan. Gunnison, Colorado, USA.

Gunnison County. 2013. Gunnison sage-grouse conservation website. Gunnison, County, USA, <http://www.gunnisoncounty.org/sage_grouse_strategic_committee.html>. Accessed July 18, 2013.

Gunnison Sage-grouse Rangewide Steering Committee. 2005. Gunnison sage-grouse rangewide conservation plan. Colorado Division of Wildlife, Denver, Colorado, USA.

Healy, S. 2009. Toward an epistemology of public participation. Journal of Environmental Management 90:1644–1654.

Hegger, D., M. Lamers, M., A. Van Zeijl-Rozema, and C. Dieperink. 2012. Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. Environmental Science and Policy 18:52–65.

Hupp, J. W., and C. E. Braun. 1989. Topographic distribution of sage-grouse foraging in winter. Journal of Wildlife Management 53:82–829.

Jasanoff, S. 2004. States of knowledge: the co-production of science and social order. Routledge, New York, New York, USA.

Kofinas, G., A. 2002. Community contributions to ecological monitoring: knowledge co-production in the U.S.–Canada Arctic borderlands. Pages 54–91 *in* I. Krupnik and D. Jolly, editors. The earth is faster now: indigenous observations of Arctic environmental change. ARCUS, Fairbanks, Alaska, USA.

Knapp, C. N., and M. Fernandez-Gimenez. 2009. Knowledge in practice: documenting rancher local knowledge in Northwest Colorado. Rangeland Ecology and Management. 62:500–509.

Lewicki, R. J., B. Gray, and M. Elliott. 2003. Making sense of intractable environmental conflicts: frames and cases. Island Press, Washington, D.C., USA.

Low, B., S. R. Sundaresan, I. R. Fischhoff, and D. I. Rubenstein. 2009. Partnering with local communities to identify conservation priorities for endangered Grevy's zebra. Biological Conservation 142:1548–1555.

Ludwig, D. 2001. The era of management is over. Ecosystems 4:758–764.

Lupis, S. G., T. A. Messmer, and T. Black. 2006. Gunnison sage-grouse use of conservation reserve program fields in Utah and response to emergency grazing: a preliminary evaluation. Wildlife Society Bulletin 34:957–962.

Morrow, M. E., T. A. Rossignol, and N. J. Silvy. 2004. Federal listing of prairie grouse: lessons from the Attwater's prairie-chicken. Wildlife Society Bulletin 32:112–118.

Oyler-McCance, S. J., K. P Burnham, and C. E. Braun. 2001. Influence of changes in sagebrush on Gunnison sage-grouse in southwestern Colorado. Southwestern Naturalist 46:323–331.

Oyler-McCance, S. J., and J. St John. 2010. Characterization of small microsatellite loci for use in non-invasive sampling studies of Gunnison sage-grouse (*Centrocercus minimus*). Conservation Genetics Resources 2:17–20.

Oyler-McCance, S. J., J. St John, S. E. Taylor, A. D. Apa, and T. W. Quinn. 2005. Population genetics of Gunnison sage-grouse: implications for management. Journal of Wildlife Management 69:630–637.

Peloquin, C., and F. Berkes. 2009. Local knowledge, subsistence harvests, and social-ecological complexity in James Bay. Human Ecology 37:533–545.

Prather, P. R., and T. A. Messmer. 2010. Raptor and corvid response to power distribution line perch deterrents in Utah. Journal of Wildlife Management 74:796–800.

Schroeder, M. A., C. L. Aldridge, A. D. Apa, J. R. Bohne, C. E. Braun, S. D. Bunnell, J. W. Connelly, P. A. Deibert, S. C. Gardner, M. A. Hilliard, G. D. Kobriger, S. M. McAdam, C. W. McCarthy, J. J. McCarthy, D. L. Mitchell, E. V. Rickerson, and S. J. Stiver. 2004. Distribution of sage-grouse in North America. Condor 106:363–376.

Stiver, J. R., A. D. Apa, T. E. Remington, and R. M. Gibson. 2008. Polygyny and female breeding failure reduce effective population size in the lekking Gunnison sage-grouse. Biological Conservation 141:472–481.

Stokstad, E. 2005. What's wrong with the Endangered Species Act? Science 309:2150–2152.

Turnbull, D. 1997. Reframing science and other local knowledge traditions. Futures 29:551–562.

U.S. Fish and Wildlife Service. 2010. Determination of the Gunnison sage-grouse as a threatened or endangered species. Federal Register 75:59804–59863.

U.S. Fish and Wildlife Service. 2013*a*. Endangered species U. S. Fish and Wildlife Service, Washington, D.C., USA, <http://www.fws.gov/endangered>. Accessed July 18, 2013.

U.S. Fish and Wildlife Service. 2013*b*. Endangered and threatened wildlife and plants; endangered status for the Gunnison sage grouse. Federal Register 78:2486–2538.

U.S. Fish and Wildlife Service. 2013*c*. Greater sage-grouse. U. S. Fish and Wildlife Service, Washington, D. C., USA, <http://www.fws.gov/mountain-prairie/species/birds/sagegrouse>. Accessed July 18, 2013.

Walsh, D. P., J. R. Stiver, G. C. White, T. E. Remington, and A. D. Apa. 2010. Population estimation techniques for lekking species. Journal of Wildlife Management 74:1607–1613.

Wondolleck, J. M., and S. L. Yaffee. 2000. Making collaboration work: lessons from innovation in natural resource management. Island Press, Washington D.C, USA.

Wynne, B. 1992. Misunderstood misunderstanding: social identities and the public uptake of science. Public Understanding of Science 1:281–304.

Young, J. R., C. E. Braun, S. J. Oyler-McCance, J. W. Hupp, and T. W. Quinn. 2000. A new species of sage-grouse (*Phasianidae : Centrocercus*) from southwestern Colorado. Wilson Bulletin 112:445–453.

Young, J. R., J. W. Hupp, J. W. Bradbury, and C. E. Braun. 1994. Phenotypic divergence of secondary sexual traits among sage-grouse (*Centrocercus Urophasianus)*. Animal Behavior 47:1353–1362.

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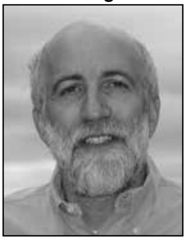

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